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DELTA VELORUM IS AN ECLIPSING BINARY

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Delta Velorum (HR 3485, HD 74956, HIP 42913) has been known as a quadruple system for many years as IDS 08419–5420 (Jeffers et al., 1963). The system contains two common proper motion (CPM) pairs, AB (2″) and CD (6″), separated by ∼ 69″. The brighter pair, δ Vel (A1V, $V = 1.96$, $B - V = +0.04$, according to Simbad) comprises a bright A-type star and a companion of unknown spectral type, three magnitudes fainter. The primary component was itself resolved as a double star by speckle interferometry (0.″6) in 1978 (Tango et al., 1979) and then by the Hipparcos satellite (0.″736, $\Delta H_{\rm p} = 3.58$, Perryman et al., 1997), although this knowledge has not made its way to all the catalogues. The CCDM (Dommanget & Nys, 1994) and the MSC (Tokovinin, 1997) only mention the four well known components. The WDSC (Worley & Douglass, 1996), the Third Catalogue of Interferometric Measurements of Binary Stars (Hartkopf et al., 2000) and the GCPD (Mermilliod et al., 1997) do include the sub-arcsecond component.

On July 1, 1997, a drop of ∼ 0.$^{\rm m}$3 in δ Vel's brightness was observed visually by Otero (2000a), who went on to observe three more fadings during 1998 and 1999. Independently, Fieseler (2000) reported a fading in the engineering data of the Galileo star scanner observations of δ Vel, on June 19, 2000. Examination of the only other set of Galileo observations of δ Vel, which was made in 1989, shows a particularly well observed eclipse (see Figure 1). Hipparcos also observed δ Vel but apart from one observation of poor

Table 1: Times of minima

JD	Cycle	$O - C$	Min	Mag.	Comment
2447851.692	0	0.00	II	2.2	UB Galileo
2450631.5	62	0.10	I	2.2	vis Otero
2450831.7	66	0.10	II	2.2	vis Otero
2451147.8	73	0.15	II	2.1	vis Otero
2451308.65	77	0.00	I	2.3	vis Otero
2451715.1	86	0.10	I	> 2.1	UB Galileo
2451850.45	89	0.00	I	2.4	vis Jansen
2451869.8	89	−0.24	II	2.1	vis various

reliability the 110 observations, made fairly evenly over $\sim$ 1200 days, show that δ Vel was constant to within $\sim 0\overset{m}{.}01$ at these times.

From an analysis of all the observations available, Lloyd (2000) and Otero (2000b) independently were able to fit an eccentric orbit with a period of approximately 45.16 days, which was consistent with both the eclipses and the out-of-eclipse observations, principally from Hipparcos. An international observing campaign across the southern hemisphere using this ephemeris resulted in the visual detection of eclipses on November 1st and 21st, 2000, near the predicted times. The times of minima from all the eclipses are gathered in Table 1 and were used to derive the improved ephemeris,

$$\mathrm{JD_I} = 2447832.10\,(\pm\,0.05) + 45.150\,(\pm\,0.001) \times E,$$
$$\mathrm{JD_{II}} = 2447851.692\,(\pm\,0.003) + 45.150\,(\pm\,0.001) \times E.$$

The best observed eclipse is that seen by Galileo in 1989 and this is shown in Figure 1 together with α Leonis for comparison. The Galileo star scanner is used for spacecraft orientation, and not for science, so the data are not calibrated. The star scanner uses an unfiltered photomultiplier tube with a response covering the Johnson U and B bands, peaking at $\sim$ 4300 Å. The light curve shows an almost complete eclipse, with a full width of 1.0 days, and a depth of $0\overset{m}{.}30$.

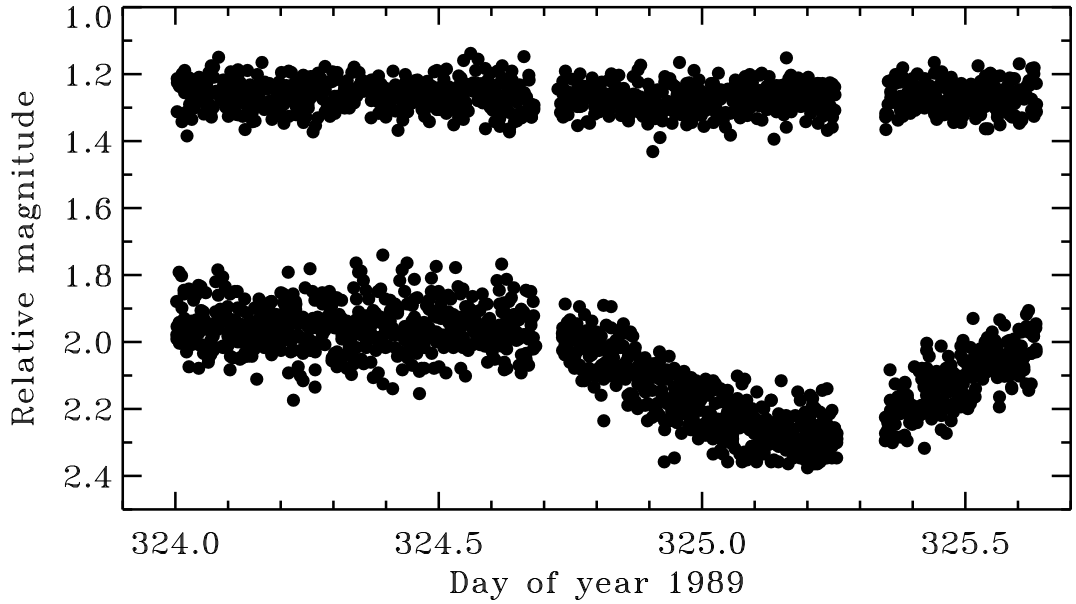

Figure 1. The light curve around secondary eclipse observed by the Galileo star tracker. The magnitudes are in the natural system of the detector normalised to the V magnitude of δ Vel. Observations of α Leonis are shown for comparison

The 2000 Galileo observations have poorer coverage than the 1989 data as Galileo's telemetry rates were lower, because the spacecraft was further from the Earth. Also software was introduced to suppress discordant measurements, which means that observations below $\sim 2\overset{m}{.}15$ are not reported by the spacecraft. Unfortunately this makes it very difficult to compare the two eclipses and assess the relative depths. The other eclipses observed visually do show a marginal but systematic difference. The three secondary eclipses typically reach 2.1 or 2.2, which is consistent with the 1989 Galileo observations, while the three primary eclipses observed were all deeper than 2.2, probably reaching 2.3.

There is also some suggestion in the visual observations that the primary eclipse is shorter than the secondary. As the orbit is eccentric, secondary eclipse occurs at $\phi = 0.43$, and the period quite long, it is possible that the system is elliptical enough to show differences in the width of the eclipses.

Given that there are three resolved components of δ Vel it may be considered that there is a possible uncertainty in the identification of the star responsible for the variations. However, the variable is unambiguously the brightest component, A. The close companions Aa and B each contribute $\sim 0\overset{\mathrm{m}}{.}05$ to the total light of the system so they cannot be responsible for the observed level of variation.

In the absence of any other information it would appear that both stars in the eclipsing binary are relatively similar. Any substantial difference would reveal itself in the eclipses, and this appears to be small. Without an accurate description of the primary eclipse, an orbital solution and detailed modelling, it is impossible to draw any definitive conclusion. However, if the difference between the eclipses is only $\sim 0\overset{\mathrm{m}}{.}1$ then this points to only a small difference in temperature and radius between the two components. The spectral type, given variously as A0V or A1V, is probably composite, and the system is probably a double-lined spectroscopic binary, with $K > 50$ km s^{-1}. The Bright Star Catalogue notes that the velocity is possibly variable, and quotes two rather different values of the $v \sin i$, 0 and 80 km s^{-1}.

We conclude that δ Velorum A is an eclipsing binary star probably containing two early main-sequence A-type stars. The δ Vel system now contains six components. The spectroscopic binary in an eccentric orbit, the close companions Aa and B, and the more distant CPM pair CD.

Further photometric and spectroscopic observations that will help in modelling the system are encouraged.

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